An Undertaking of Bhaktapur Municipality

KHWOPA ENGINEERING COLLEGE

Affiliated to Purbanchal University, Estd. 2001
(Dedicated To Country & People)

Final Year Project –Mid term Defense

"STRUCTURAL ANALYSIS AND DESIGN OF RCC BUILDING IN SLOPPY AREA"

Presented By : Group F

- **Nitesh Manandhar (780256)**
- **Ronij Koju (780276)**
- **Shashswot Shrestha (780287)**
- **Shasi Shekhar Sapkota (780288)**
- **Subash Karki (780290)**

Project Supervisor:
Er. Sudip Karanjit

Date:2082-09-11

INTRODUCTION

- RCC is composite material known for its high strength, durability and cost effectiveness.
- It's a mix of concrete and steel so it is suitable for both strength and flexibility.
- And since Nepal lies in earthquake prone area, so demand of earthquake resistant RCC buildings are high.

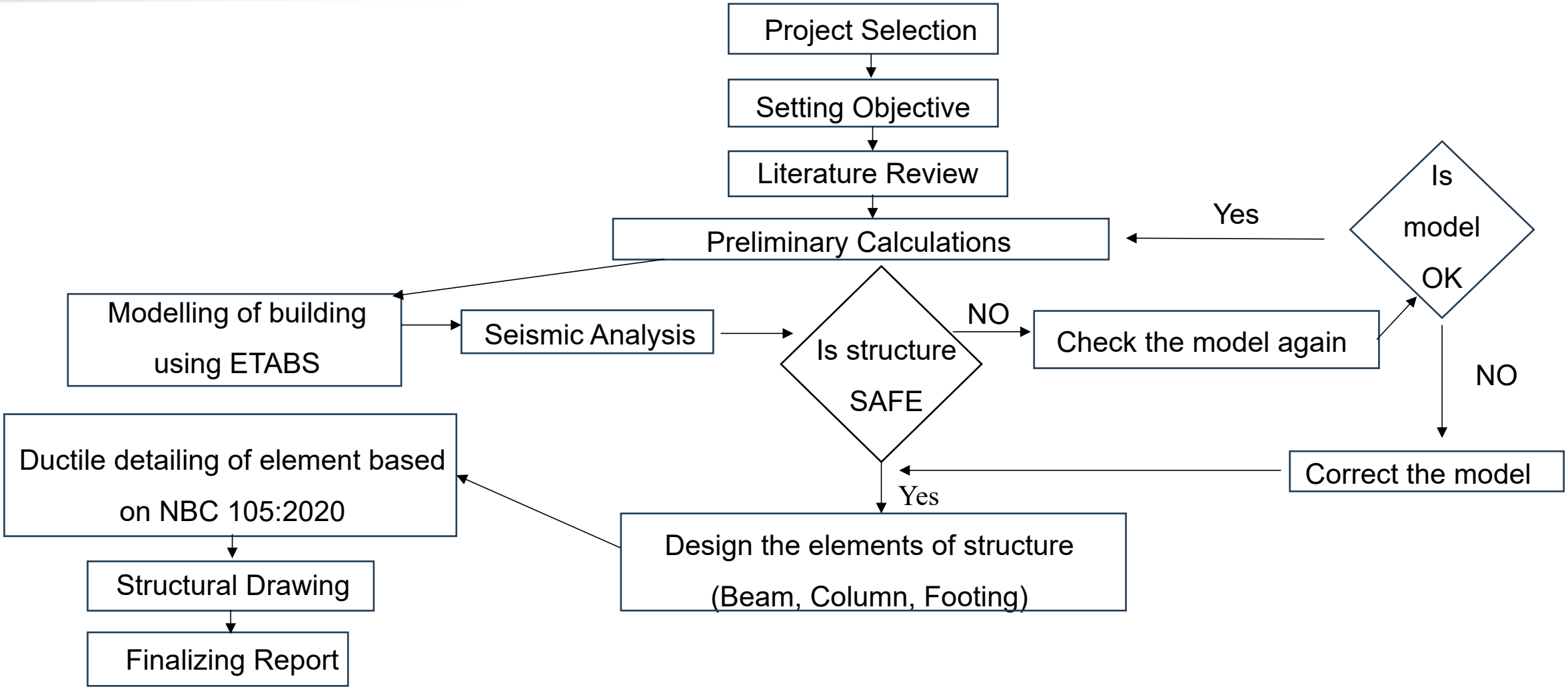
OBJECTIVES

- Perform complete structural analysis using IS codes and software tools.
- Analyze load calculations and member layouts.
- Design and detail reinforcement.
- Estimate total cost and prepare BOQ.

SCOPE

- Design of multi storeyed commercial building in slopy area.
- Load estimation: IS 875, NBC 105:2020.
- Structural modeling and detailing.
- BOQ and cost estimation.

METHODOLOGY

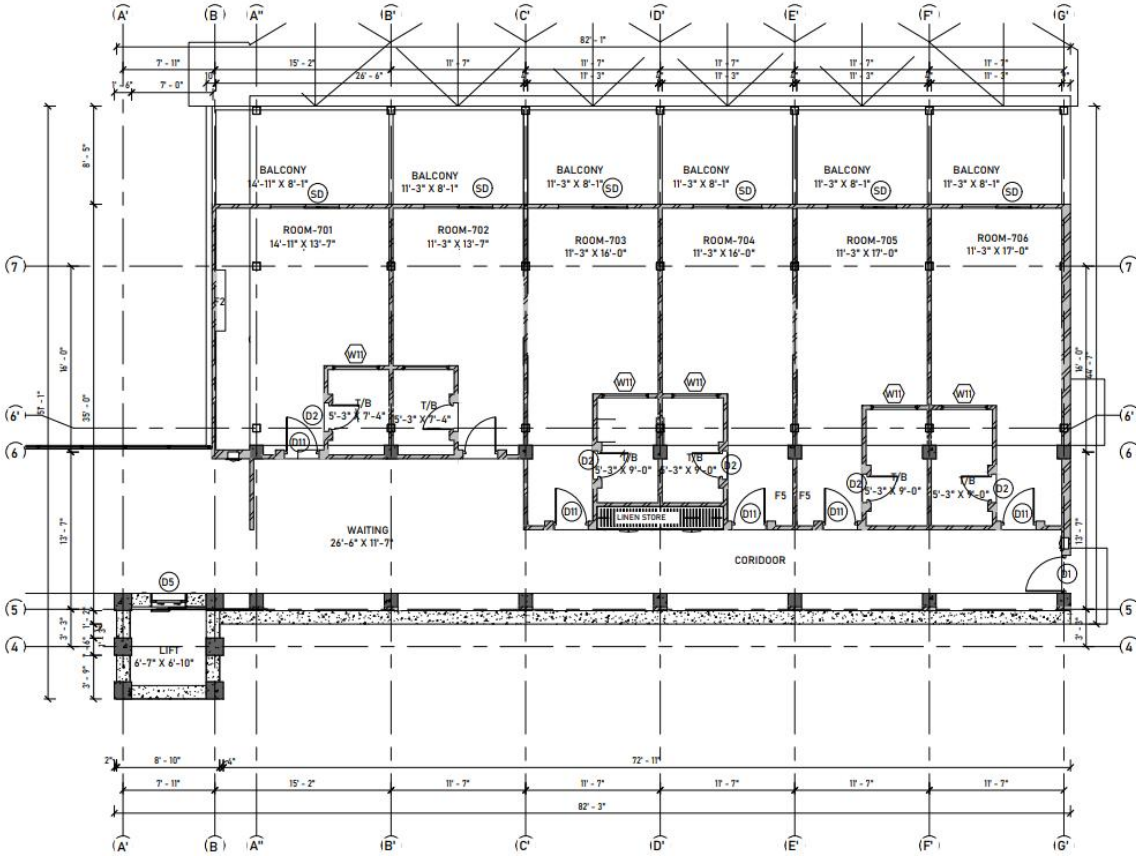


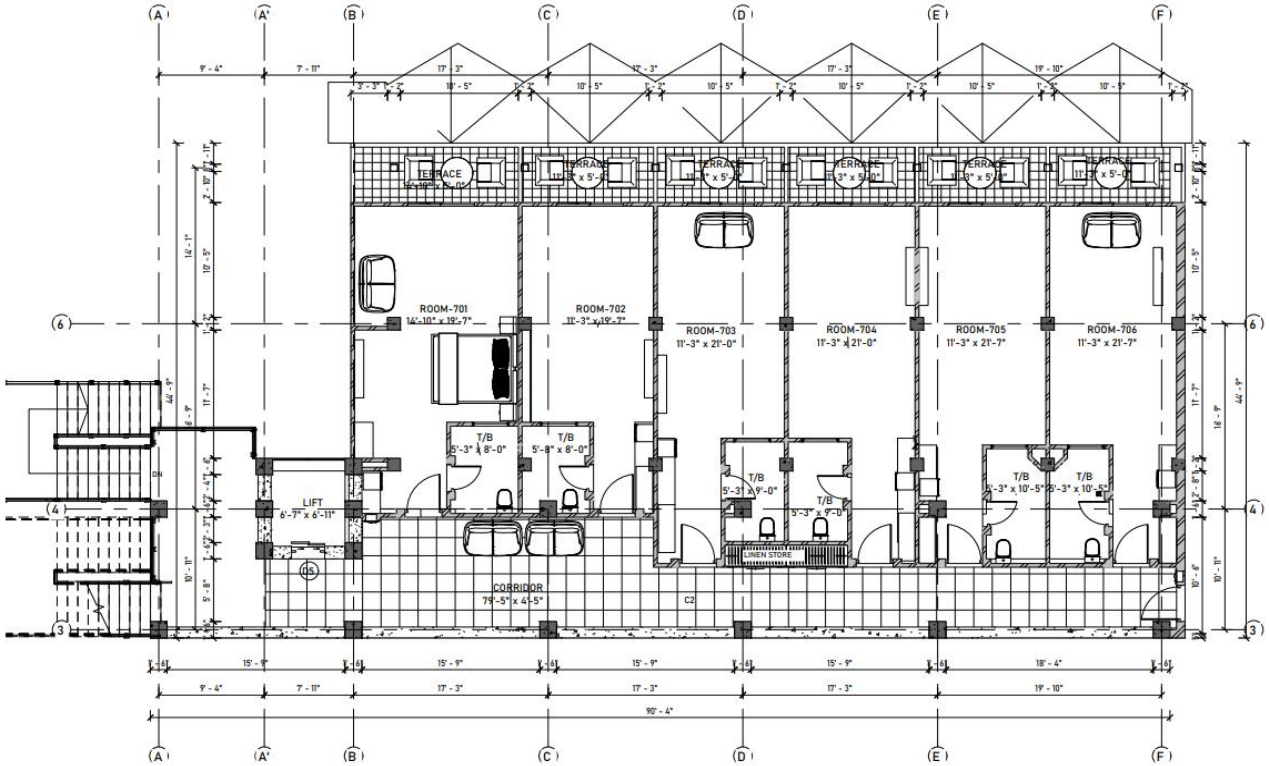
Flow Chart Showing Method of Project Completion

BUILDING DESCRIPTION

Type of the project	: Seismic Analysis and Design of RCC Building
Building type	: Hotel Building
Location	: Ghyampe Dada, Bhaktapur
Structural type	: Dual system (RC shear wall)
Plinth area covered	: 478.683 sq.m.
No. of story	: 6 Floor + Roof
Floor height	: 3.302 m for all floors (Total Height of Building= 26.416m)
Type of staircase	: Dog-legged, Open well
Method of analysis	: Dynamic Analysis (ETABS 2022)
Design concept	: Limit state design
Concrete Grade	: M30, M25
Reinforcement	: Fe500
Soil Type	: Very Soft Soil (Type D)
Bearing capacity	: 200 KN/m^2 (from soil investigation report)

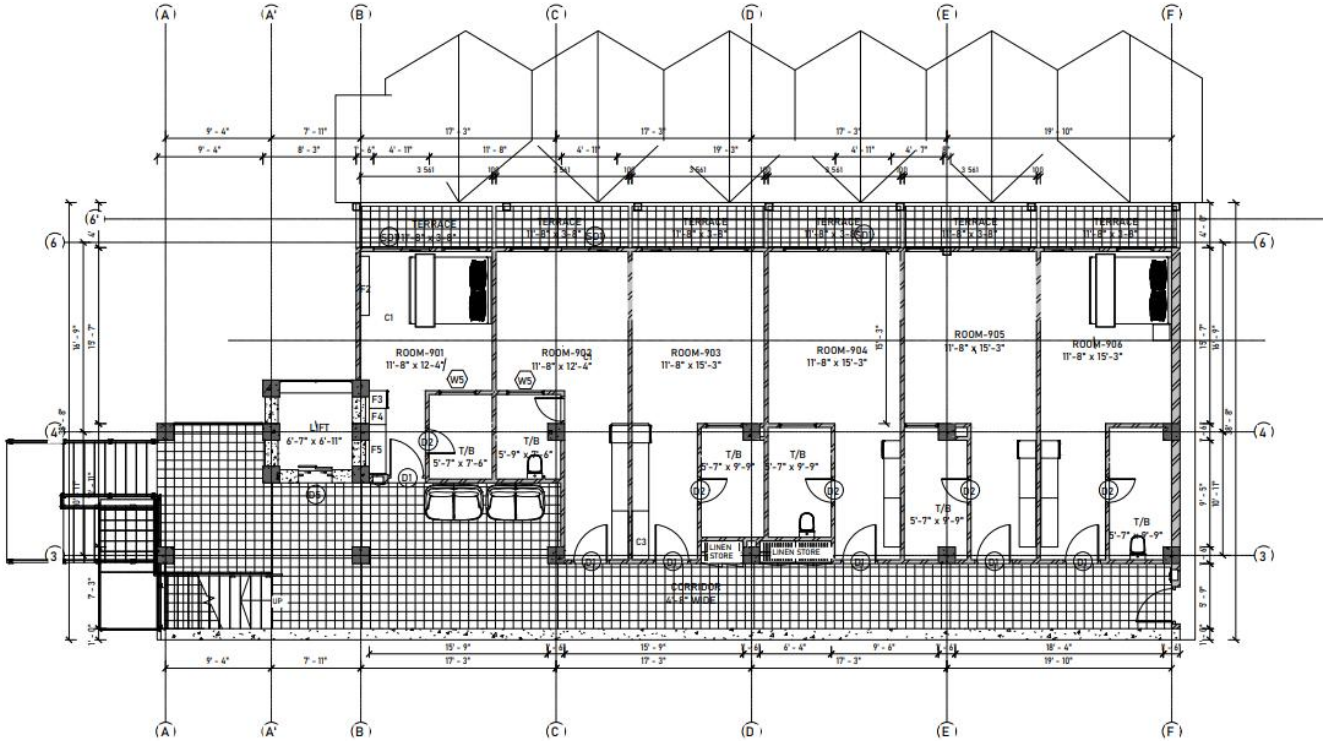
ARCHITECTURE DRAWING

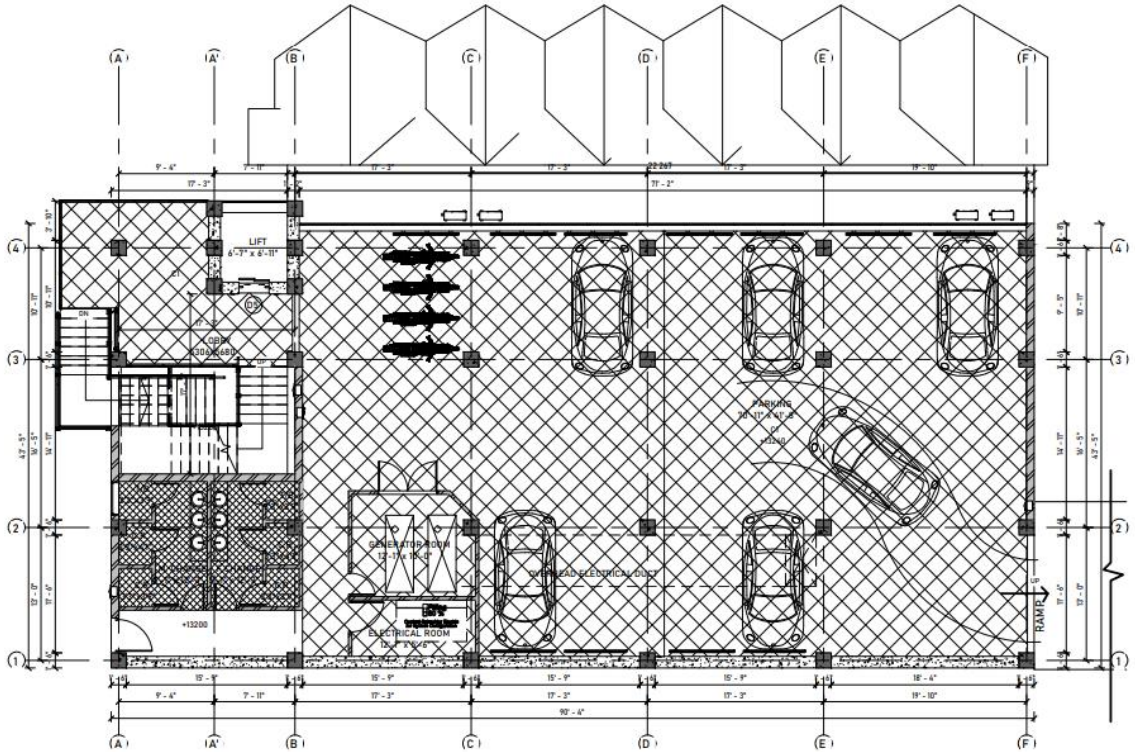




PLAN

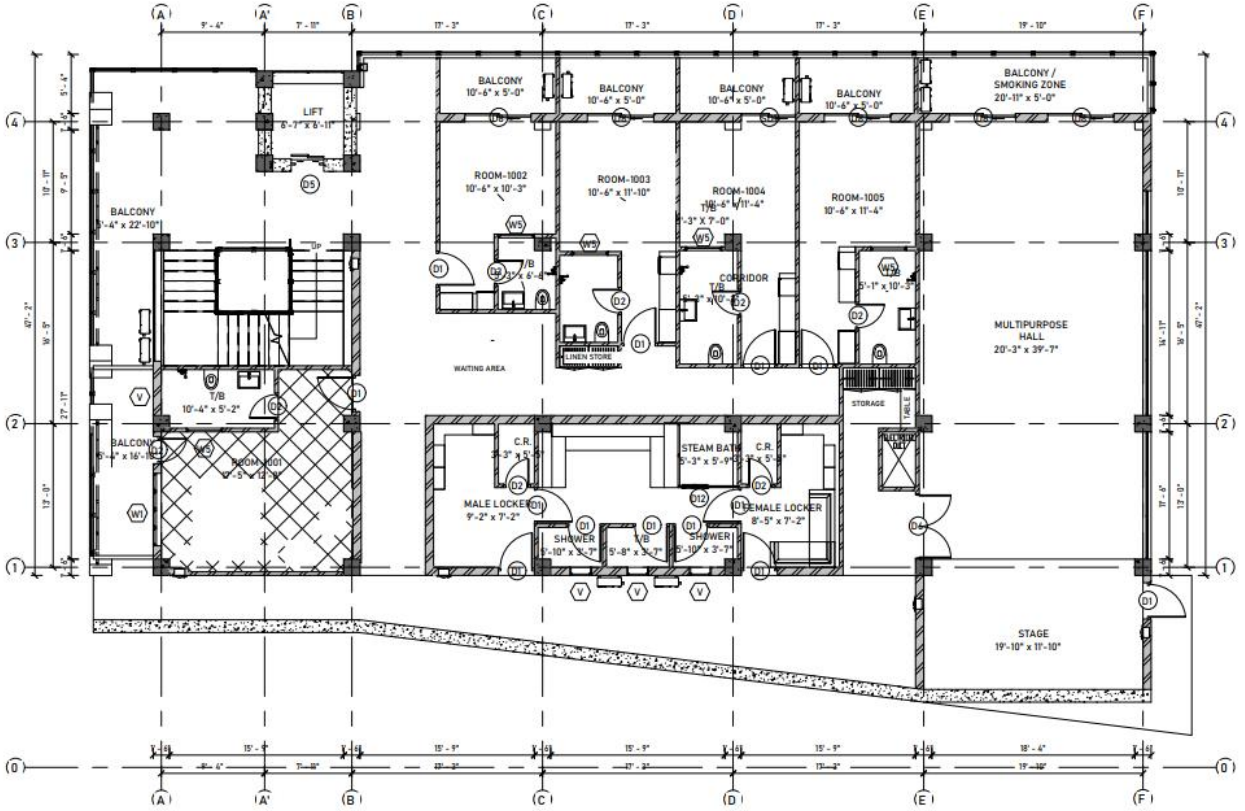
ARCHITECTURE DRAWING

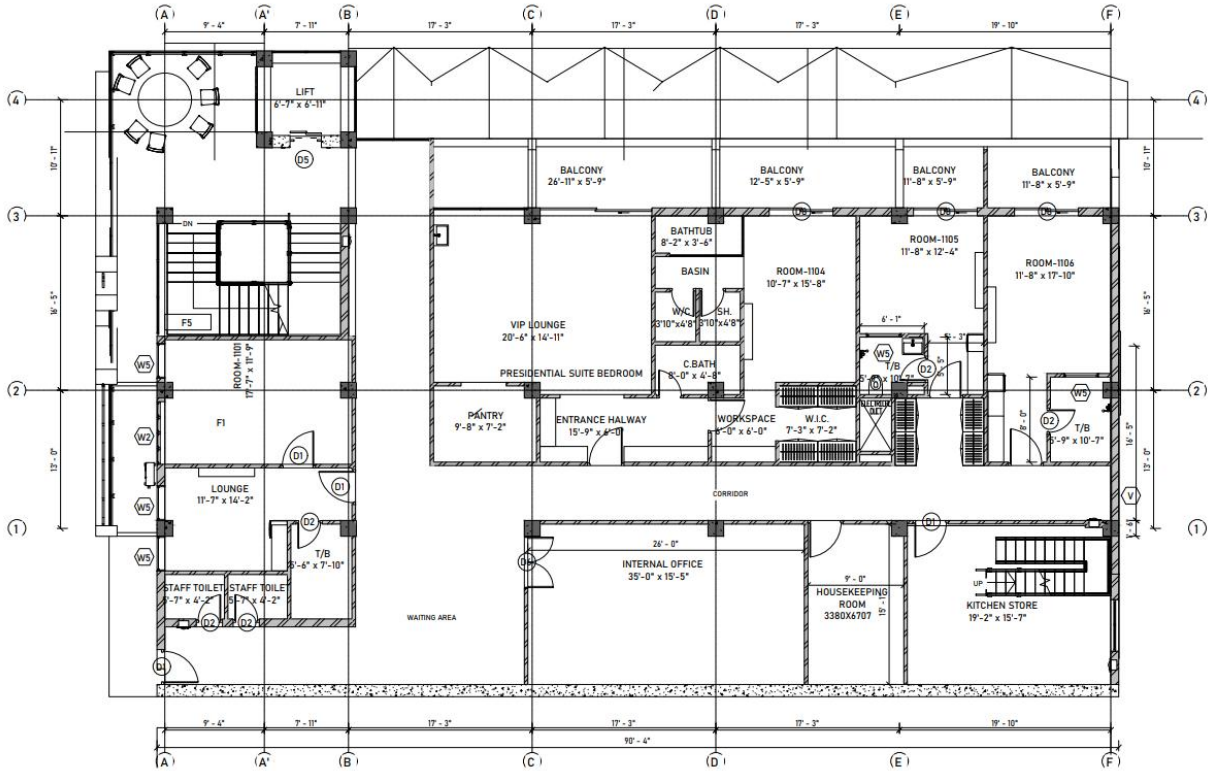




PLAN

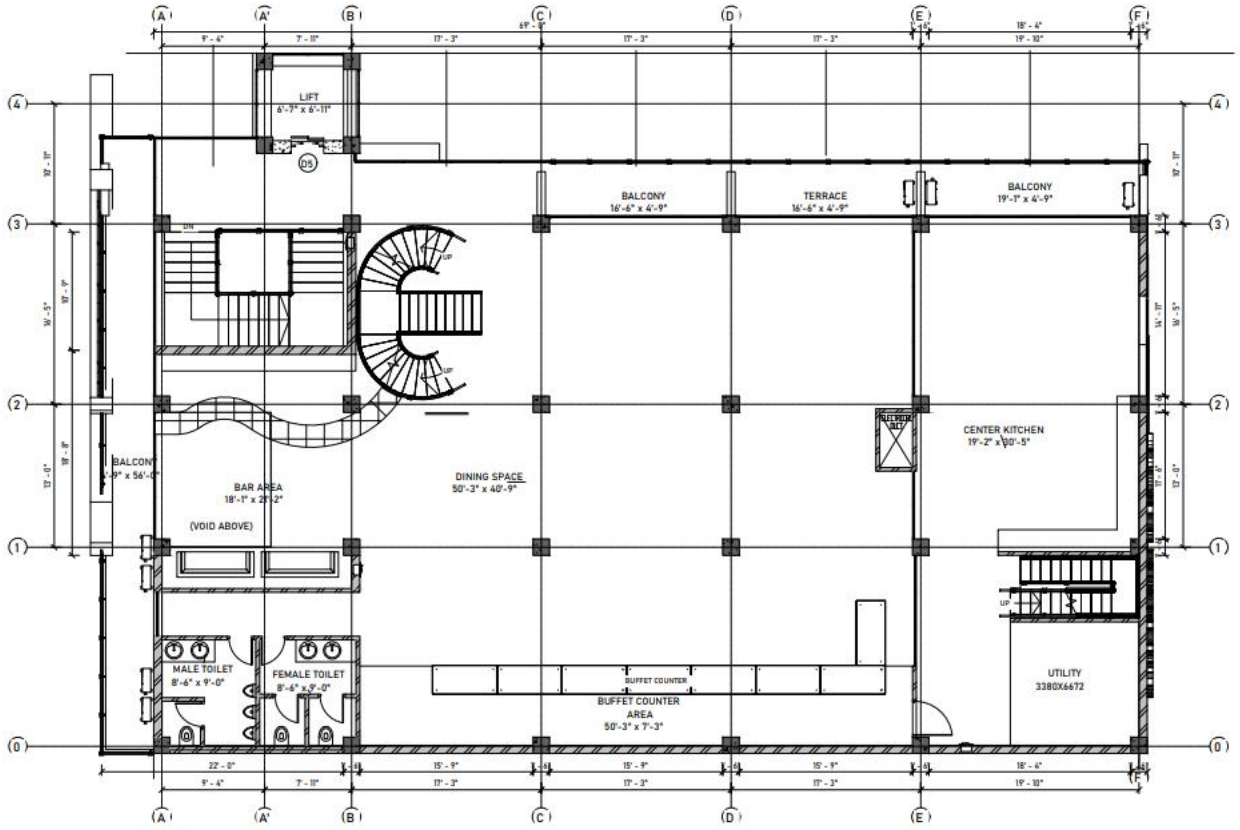
ARCHITECTURE DRAWING

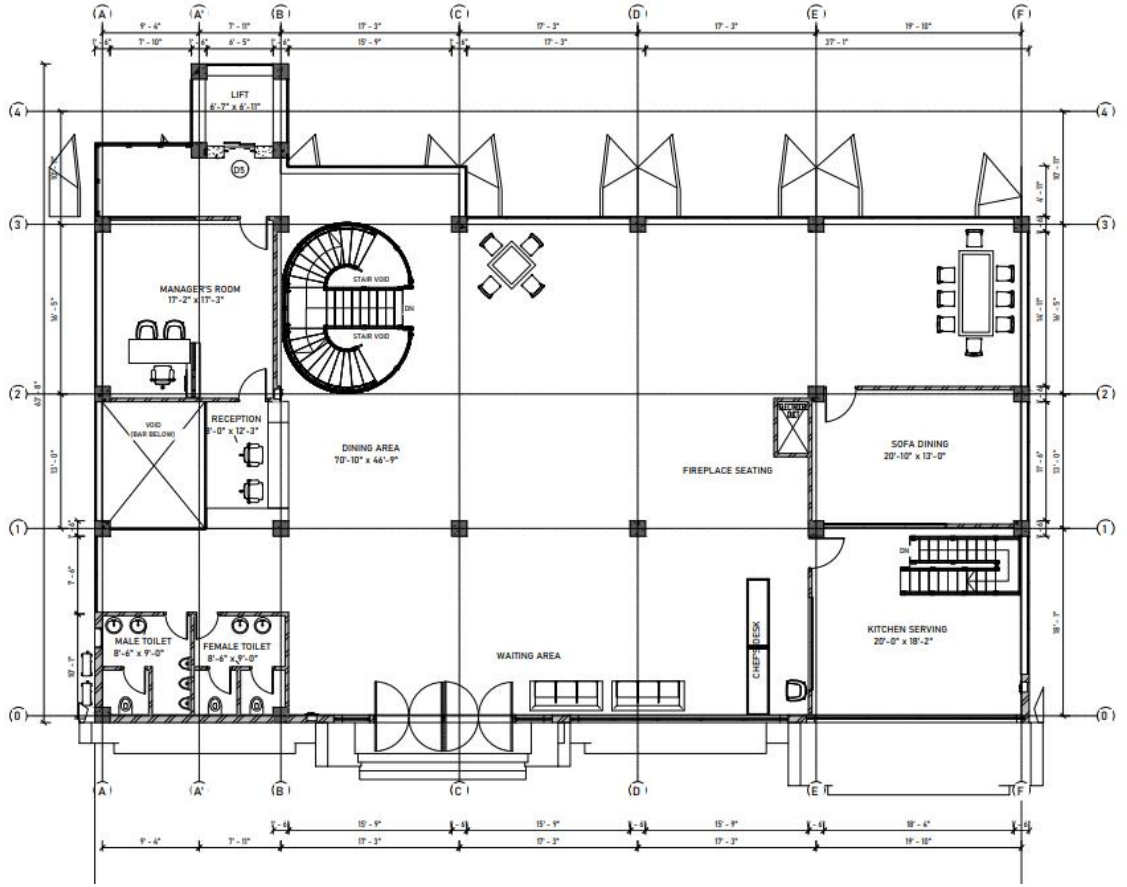




PLAN

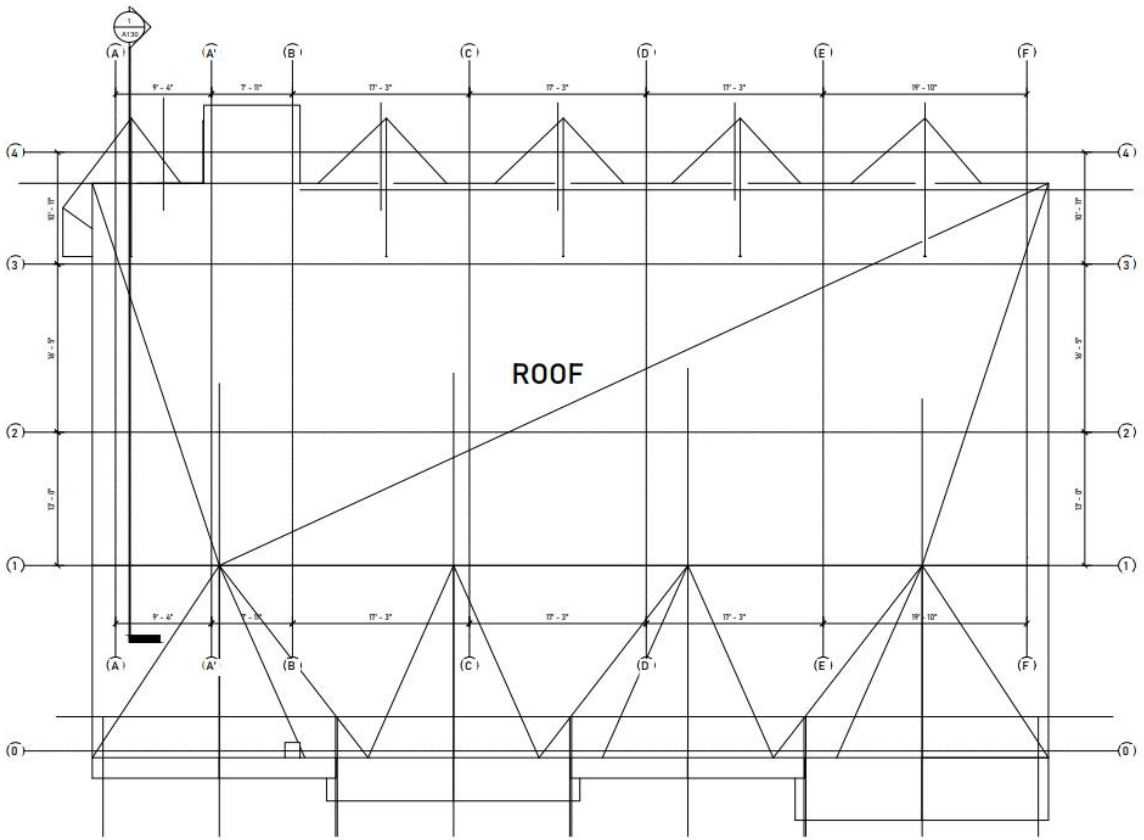
ARCHITECTURE DRAWING



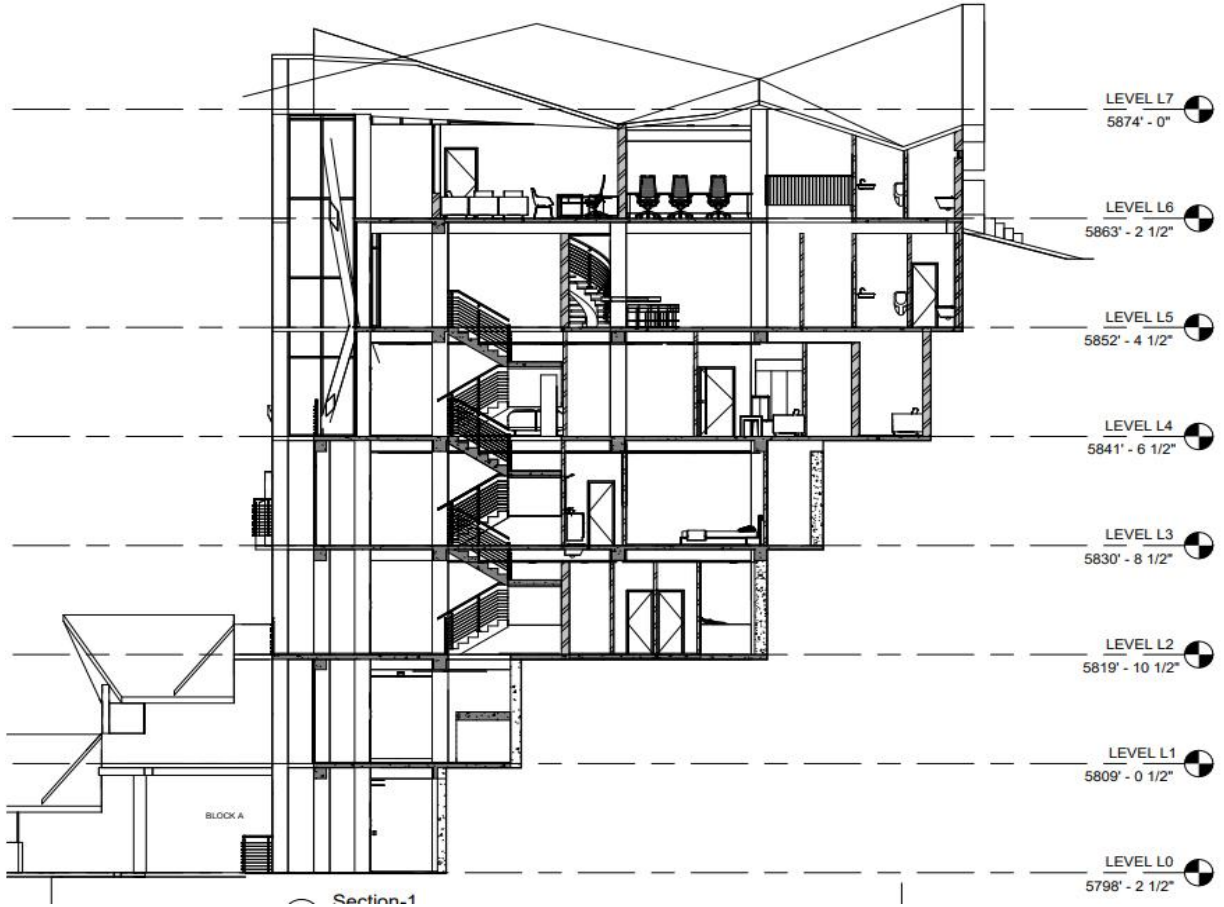


PLAN

ARCHITECTURE DRAWING

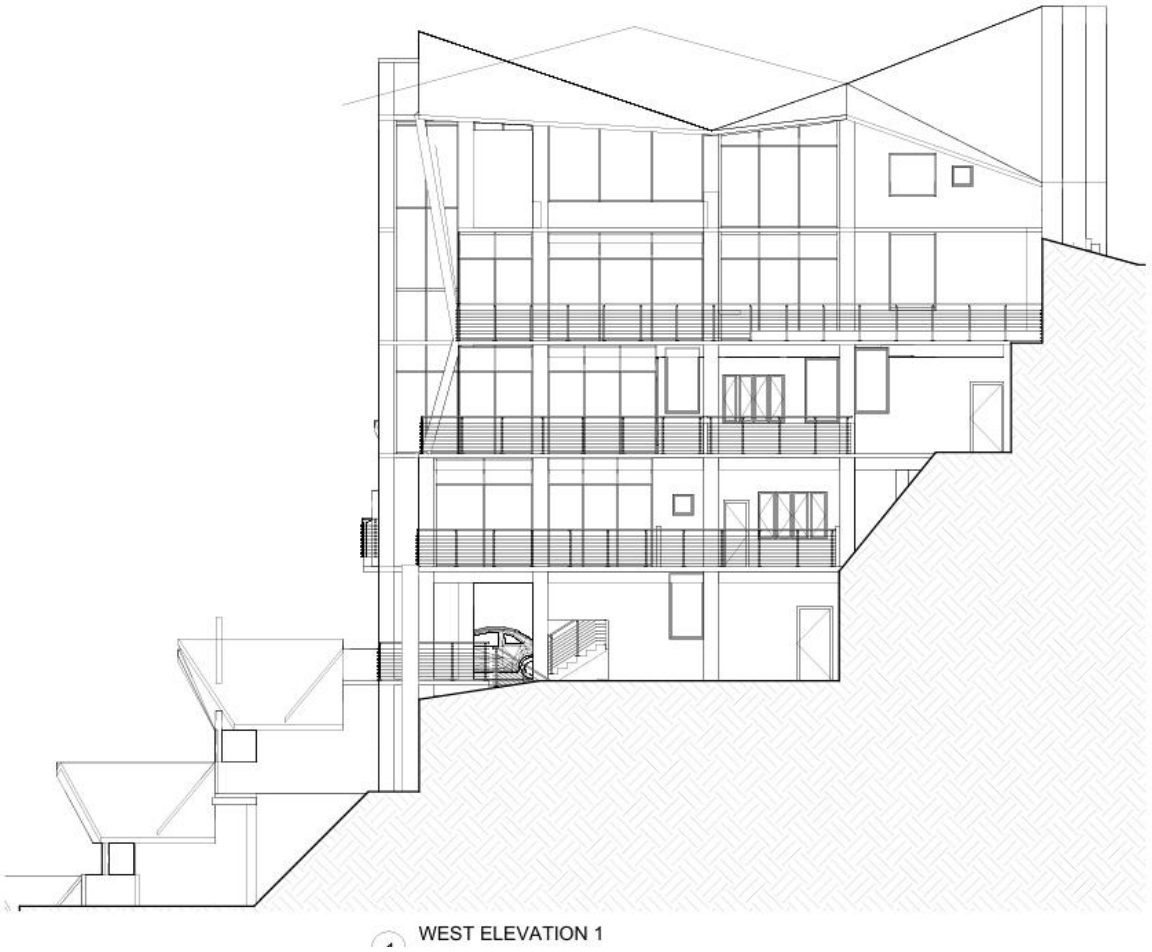


PLAN



SECTION

ELEVATION

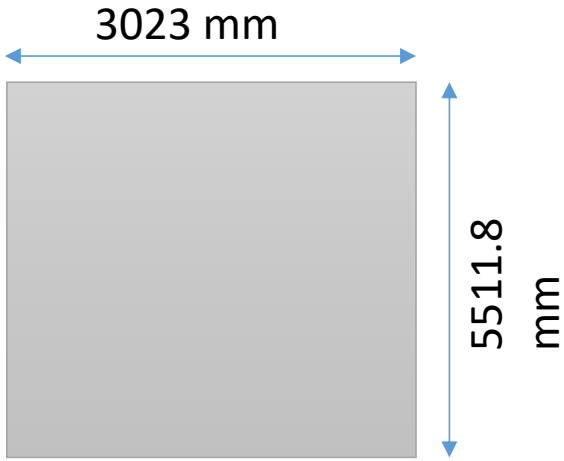


WEST ELEVATION 1

NORTH ELEVATION 1

1 : 100

PRELIMINARY DESIGN



Slab

Lx= 3023mm

Using deflection criteria ;

➢Depth required, d_{eff}=Lx/(MF*BV)

Modification factor(MF)=1.5 (From calculation and fig 4 of IS 456:2000)

Basic Value (BV) = 23 (IS 456:2000 23.2.1)

d_{req}= 3023/(1.5*23)

= 87mm

Adopt D=125mm

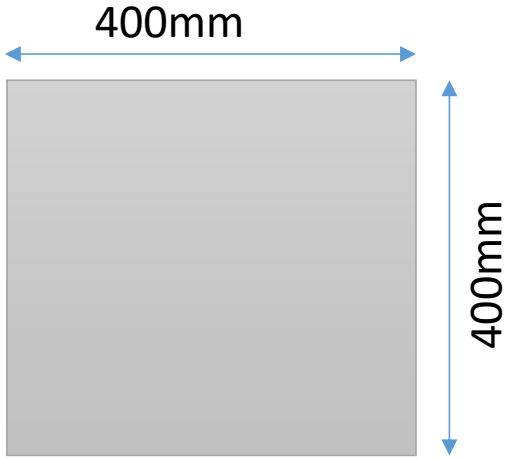
PRELIMINARY DESIGN

Description	Values	Remarks
Thumb Rule		**Primary beam**
Lx	5.2578m	5257.8mm
D=Lx/12	438.15	mm
Adopt D=	**450**	**mm**
d=D-effective cover	**420mm**	effective cover=30 mm,
Width,B= 3*D/5	270mm	≥ 200mm, OK
Adopt B=	300mm	
BxD=	(300X450)mm	

PRELIMINARY DESIGN

Description	Values	Remarks
Thumb Rule		**Secondary beam**
Lx	5.512m	5512mm
D=Lx/15	367	mm
Adopt D=	**400**	**mm**
d=D-effective cover	**370mm**	effective cover=30 mm,
Width,B= 3*D/5	220mm	≥ 200mm, OK
Adopt B=	250mm	
BxD=	(250X400)mm	

PRELIMINARY DESIGN



Column

- For Column;
- From IS Code 456:2000 Clause 39.6

Assuming 2% of gross area of column for steel

- $Pu=0.4\times fck\times Ac + 0.67\times Asc\times Fy$

Gross area(Ag)= 0.1306 m2 , Assuming Square column;

$B=D = \sqrt{Ag} = 0.3614$ m =361.4mm

Adopt Size of column = 400mm > 361.4 mm

Effective cover: 40 mm

Similarly,

Column (Intermediate Column) = (400*400) mm

Column (Face Column and corner column) = (400*400) mm

PRELIMINARY DESIGN

SUMMARY

Slab (Using Deflection Criteria)

- Effective cover = 25 mm
- Total depth of Slab (D) =125 mm

Beam (Thumb Rule)

- Effective cover = 30 mm
- Primary Beam = (300 × 450)mm
- Secondary Beam = (250 × 300)mm

Column

- Effective cover: 40 mm
- Column (Intermediate Column) = (400*400) mm
- Column (Face Column and corner column) = (400*400) mm

LUMP MASS CALCULATION

Floor	Slab (KN)	Primary beam (KN)	Second. Beam (KN)	Column (KN)	Wall (KN)	Staircase (KN)	Shear Wall (KN)	Floor Finish (KN)	Total Dead Load (KN)	Live Load (KN)	Seismic WT (KN)
Level 1	495.316	236.685	38.163	144.297	248.657	52.898	628.23	221.901	2066.147	237.752	2303.899
Level 2	1113.209	257.344	46.428	223.005	368.823	53.793	628.23	377.601	3068.433	534.341	3602.774
Level 3	1470.928	650.477	152.983	275.476	859.037	60.487	655.303	658.976	4783.667	706.046	5489.713
Level 4	1420.894	590.301	154.368	242.681	1216.622	60.487	682.98	636.56	5004.893	682.029	5686.922
Level 5	1454.959	600.932	177.355	275.476	1216.622	30.244	327.953	651.822	4735.363	931.174	5666.537
Level 6	1278.3	678.942	177.673	268.917	864.34	0	0	572.678	3840.85	818.112	4658.962
Roof truss									157.54	85.61875	243.159
										Total Load	**27651.96**

BASE SHEAR CALCULATION

Zone Factor	Z=	0.35	Clause 4.1.4
Importance Factor	I=	1.25	Clause 4.1.5
	Soil type:	D	Clause 4.1.3.4
Height of Building	H=	16.510 m	
For all other structural system	K_t=	0.05	Clause 5.1.2
Time Period	T= $1.25*K_t*H^{0.75}$	0.512 sec	Clause 5.1.2 & 5.1.3
For Equivalent Static Method	Ta=	0	Table 4-1
	Tc=	2	Table 4-1
	α=	2.25	Table 4-1
	K=	0.8	Table 4-1
Spectral Shape Factor	Ch(T)	2.25	Clause 4.1.2
Elastic Site Spectra	C(T)=Ch(T)*Z*I	0.984375	Clause 4.1.1

BASE SHEAR CALCULATION

Elastic Site Spectra for serviceability limit state	Cs(T)=0.2*C(T)	0.196875	Clause 4.2
Horizontal Base Shear Coefficient			
Dual Systems	(i) For SLS		Clause 5.4.2
	Ru=	3.5	Table 5-2
(RC Shear wall)-1	Ωu=	1.4	Table 5-2
	Ωs=	1.2	Table 5-2
	Cd(T1)= Cs(T1)/Ωs	0.1641	Clause 6.1.2
	(ii) For ULS		Clause 5.4.1
	Ru=	3.5	Table 5-2
	Ωu=	1.4	Table 5-2
	Ωs=	1.2	Table 5-2
	Cd(T1)= C(T1)/(Ru*Ωu)	0.2009	Clause 6.1.1

BASE SHEAR CALCULATION

Building Height exponent	k=	1.01	Clause 6.3
Accidental Eccentricity	e=	0.1	Clause 5.7
Allowable story drift			
	(i) For ULS: 0.025/Ru	0.007142857	Clause 8.1.3.1
	(ii) For SLS	0.006	Clause 8.1.3.1
Allowable story displacement			
	(i) For ULS: 0.025*(H/Ru)	117.9286 mm	Clause 5.6.1.1
	(ii) For SLS: 0.006*(H/Rs)	99.0600 mm	Clause 5.6.1.2

Base Shear = Cd(T1)xW = 0.2009 x 27651.966
= 5555.279 KN

MODELLING AND ANALYSIS

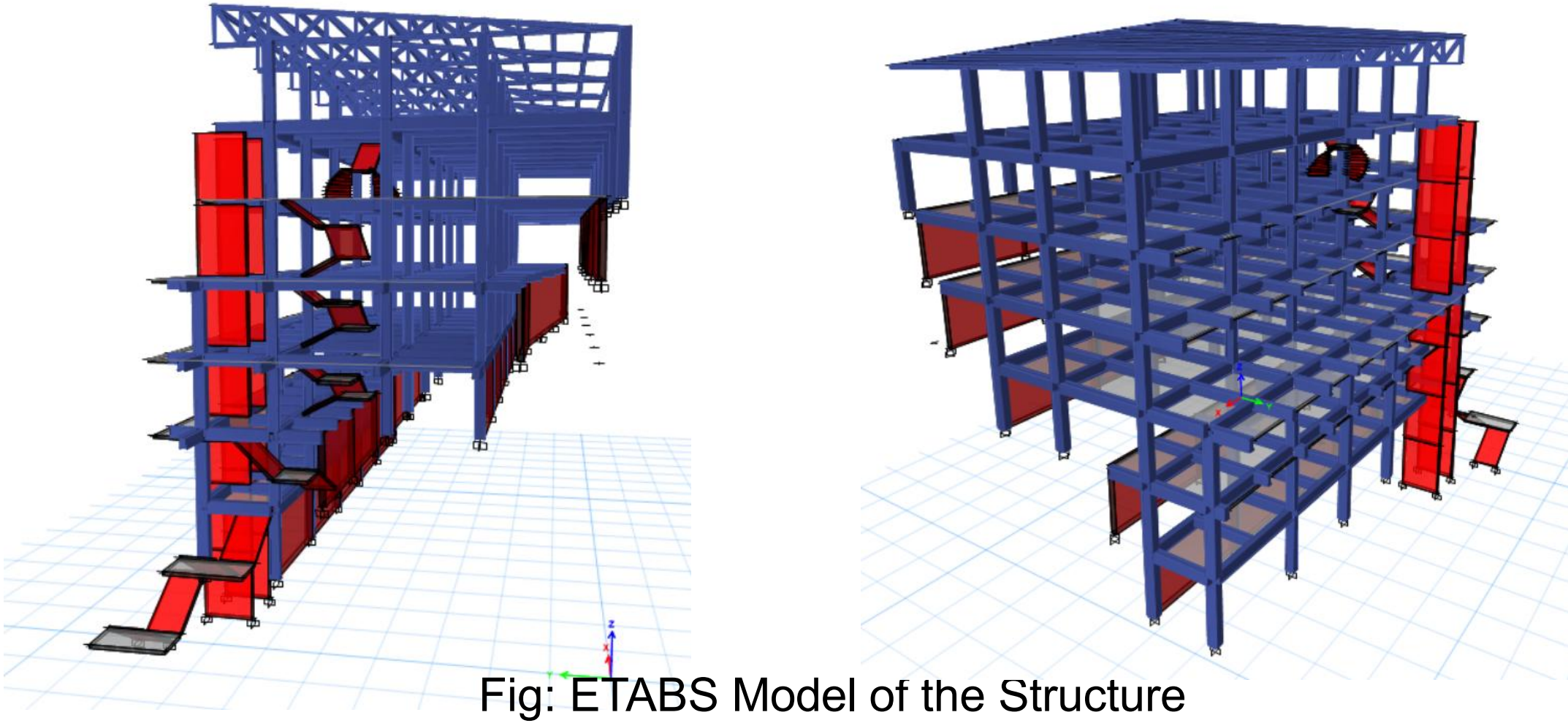


Fig: ETABS Model of the Structure

MODELLING AND ANALYSIS

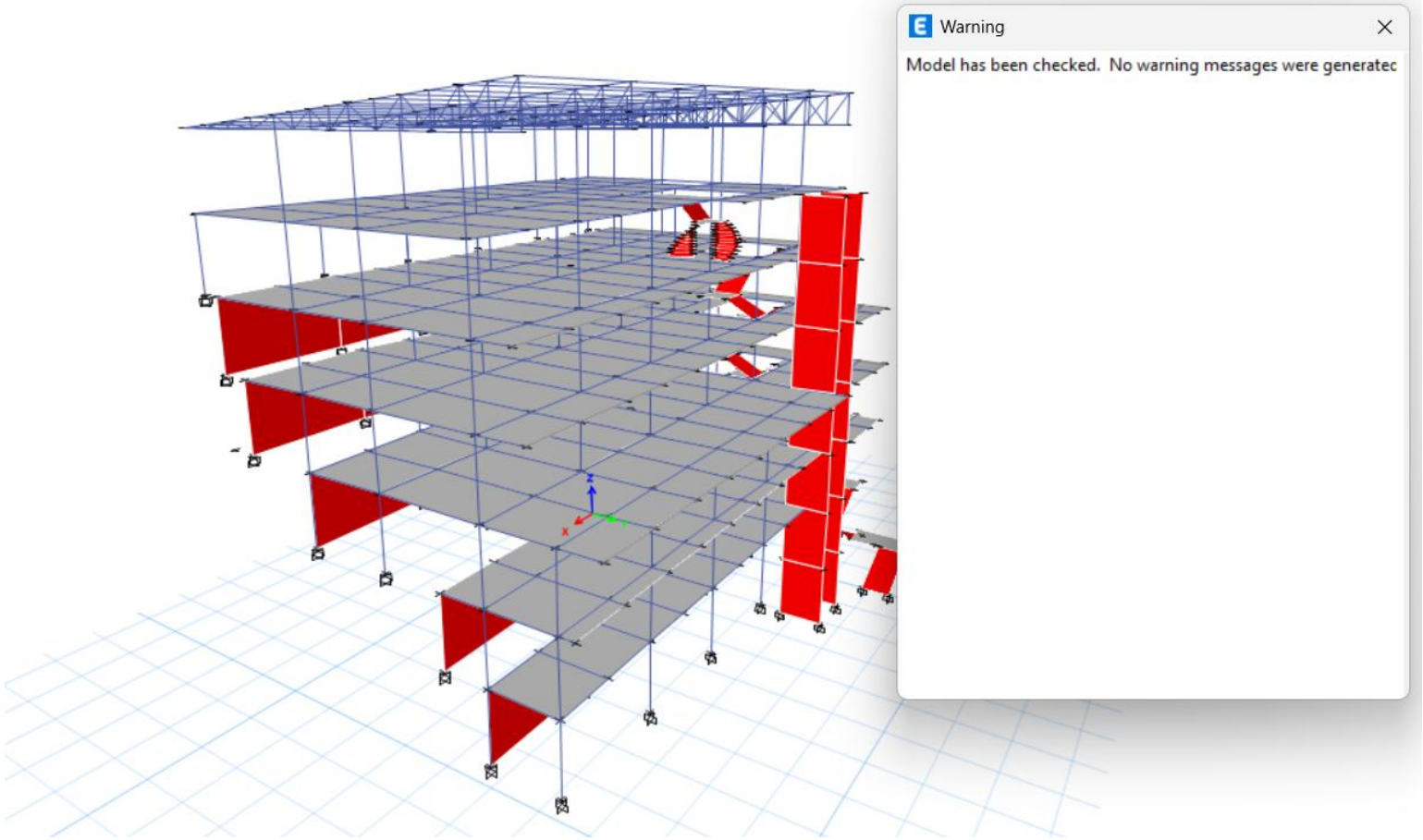


Fig: ETABS Model of the Structure

MODELLING AND ANALYSIS

File Edit Format-Filter-Sort Select Options

Units: As Noted Hidden Columns: No Sort: None
Filter: ([Output Case] = 'eqx uls1' OR [Output Case] = 'eqy uls')

	Output Case	Case Type	Step Type	Step Number	FX kN	FY kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m
▶	eqx uls1	LinStatic	Step By Step	1	-2997.7183	-4.345E-06	0	4.483E-05	-59114.7328	25645.756
	eqx uls1	LinStatic	Step By Step	2	-2997.7183	-5.174E-06	0	0.0001	-59114.7327	30128.1168
	eqx uls1	LinStatic	Step By Step	3	-2997.7183	-3.516E-06	0	3.629E-05	-59114.7328	21163.3952
	eqy uls	LinStatic	Step By Step	1	2.645E-06	-2997.7183	0	59114.7331	4.136E-05	-38968.0466
	eqy uls	LinStatic	Step By Step	2	-3.569E-06	-2997.7183	0	59114.7331	-0.0001	-46662.7973
	eqy uls	LinStatic	Step By Step	3	8.858E-06	-2997.7183	0	59114.7331	0.0001	-31273.296

For EqX and EqY(ULS):

Base reaction from Etabs = 2997.718 KN

Base reaction from manual calculation = 5555.279 KN

IRREGULARITY CHECK

According to NBC 105:2020 cl 3.2.1,
Equivalent Static Method may be used if,

a) The height of the structure is less than or equal to 15 m.
b) The natural time period of the structure is less than 0.5 secs.
c) The structure is not categorized as irregular as per Cl.5.5 and the height is less than 40 m.

- Since the height of the building is 26.416m i.e greater than 15m and the building is irregular as per clause 5.5 so, **Modal Response Spectrum Method**(MRSM) is adopted for the seismic analysis (CL.3.2) .

ECCENTRICITY AND TORSION CHECK

- Eccentricity:

The maximum eccentricity along X and Y direction was found to be 19.33% and 35.6% at story-1 and story-5 respectively.

- Torsion:

Load Case/Combo	Ratio Max/min	Check <1.5
EQx_SLS	102.455	NOT OK
EQy_SLS	6.343	NOT OK
EQx_ULS	297.75	NOT OK
EQy_ULS	1.839	NOT OK

VERTICAL IRREGULARITY CHECK

Mass irregularity

Mass Irregularity		
Floor	Mass	Check
	kg	50% EL(i±1)
7	41418.88	-
6	374546.4	OK
5	462176.2	OK
4	500078.3	OK
3	518469.9	Not OK
2	244086.2	OK
1	209417.6	Not OK
0	63752.31	Not OK
-1	10674.23	-

VERTICAL IRREGULARITY CHECK

SOFT STORY

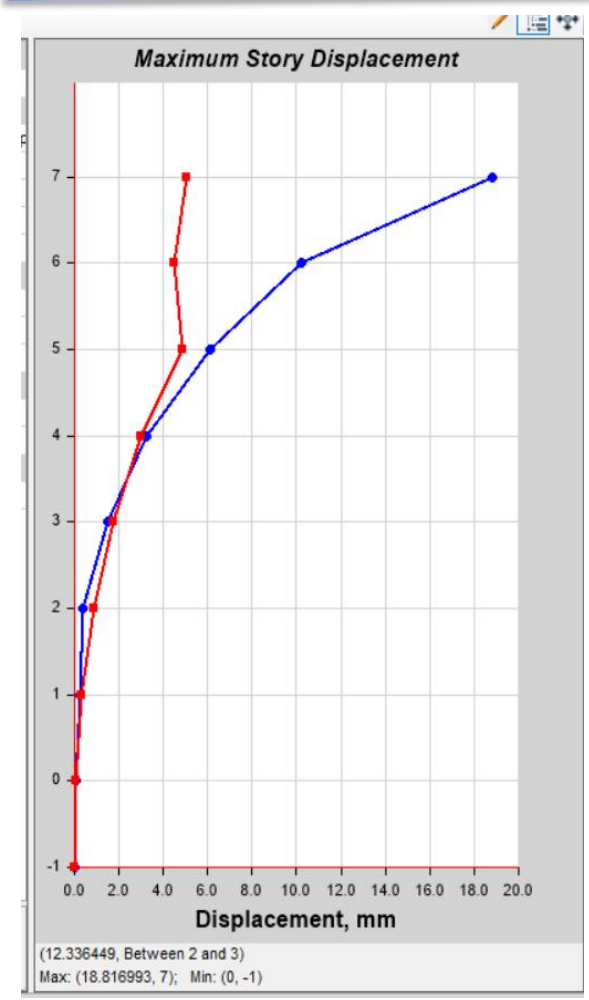
Ultimate Limit State/Serviceability Limit State								
Storey Stiffness								
	Load Case	Stiffness	Check		Load Case	Stiffness	Check	
Floor	Load	kN/m	70% of K(i+1)	80% of K(i+n)/2		kN/m	70% of K(i+1)	80% of K(i+n)/2
7	EQx	18043.74	-	-	EQy	0	-	-
6	EQx	224025.2	OK	-	EQy	0	OK	-
5	EQx	950014.7	OK	-	EQy	0	OK	-
4	EQx	661175.5	Not OK	OK	EQy	58372.3	OK	OK
3	EQx	752349.3	OK	OK	EQy	126338.6	OK	OK
2	EQx	814550.7	OK	OK	EQy	96519.76	OK	OK
1	EQx	227698	Not OK	Not OK	EQy	22813.35	Not OK	Not OK
0	EQx	0	Not OK	Not OK	EQy	516679.2	OK	OK

DISPLACEMENT AND DRIFT CHECK

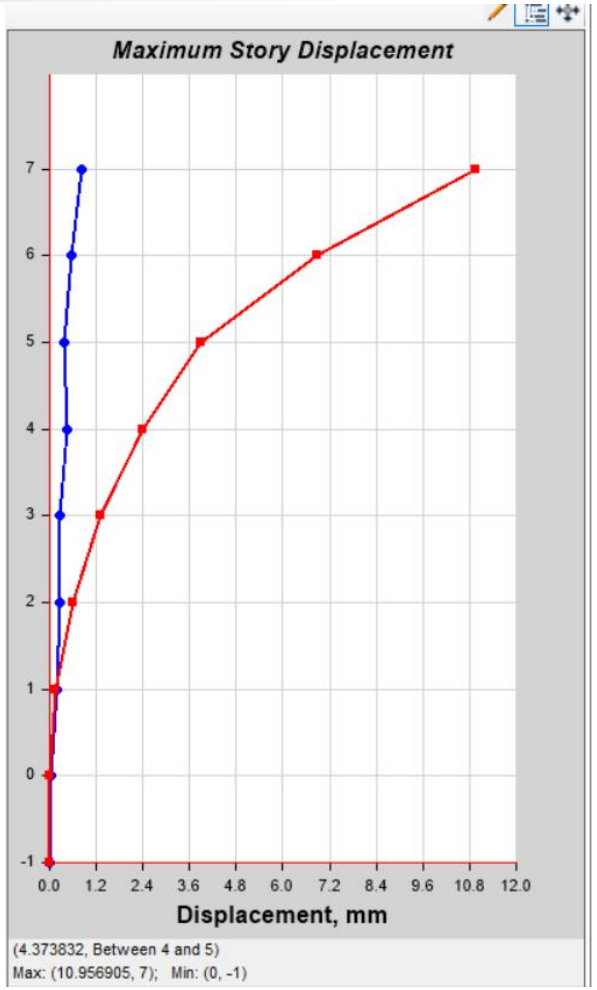
As per NBC 105:2020 cl 5.6

Displacement criteria				
	Along X Direction	**Along Y Direction**	Check	
Design displacement from ETABS in ULS	121.536	81.6375	121.536< 165.1(ok)	81.6375< 165.1(ok)
Allowable ratio ULS	0.025	0.025		
Allowable Displacement ULS =0.025*H/Rμ	165.1mm	165.1mm		
Design displacement from ETABS in SLS	18.817	10.957	18.817< 158.496(ok)	10.957< 158.496(ok)
Allowable ratio ULS	0.006	0.006		
Allowable Displacement SLS =0.006*H/R_s	158.496	158.496		
Drift Criteria				
Design Storey Drift from Etabs ULS	0.0013	0.006	0.0013 < 0.007 (ok)	0.006 < 0.007 (ok)
Allowable Storey Drift =0.025/Rμ	0.007	0.007		
Design Storey Drift from Etabs SLS	0.0025	0.0012	0.0025 < 0.006 (ok)	0.0012 < 0.006 (ok)
Allowable Storey Drift =0.006/Rs	0.006	0.006		

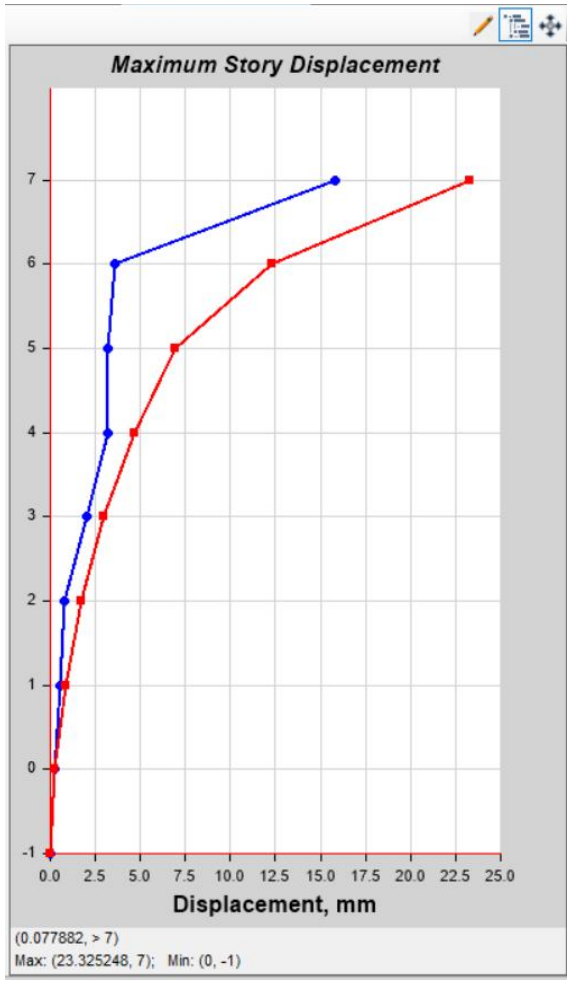
DISPLACEMENT AND DRIFT CHECK



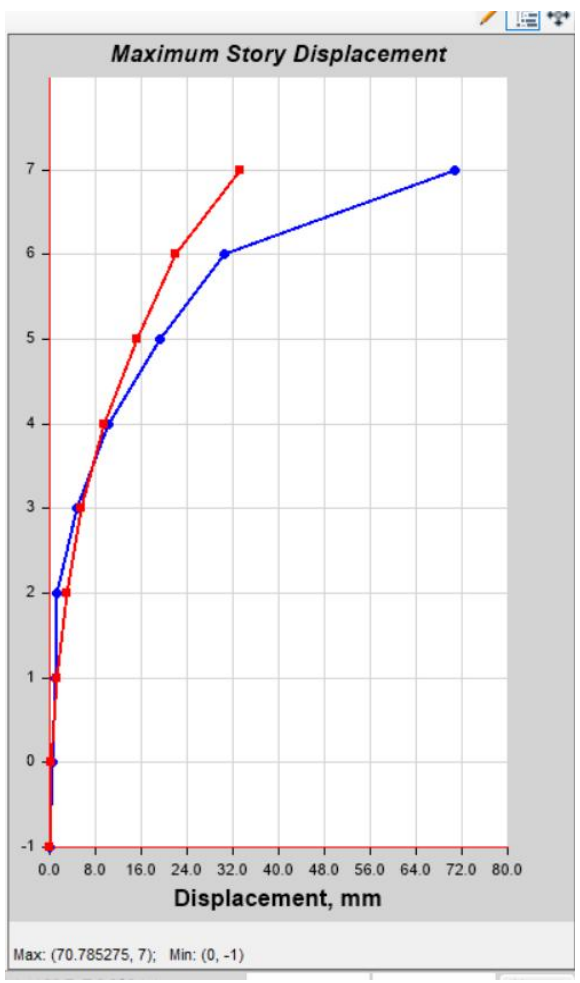
Eqx (SLS)



Eqy (SLS)

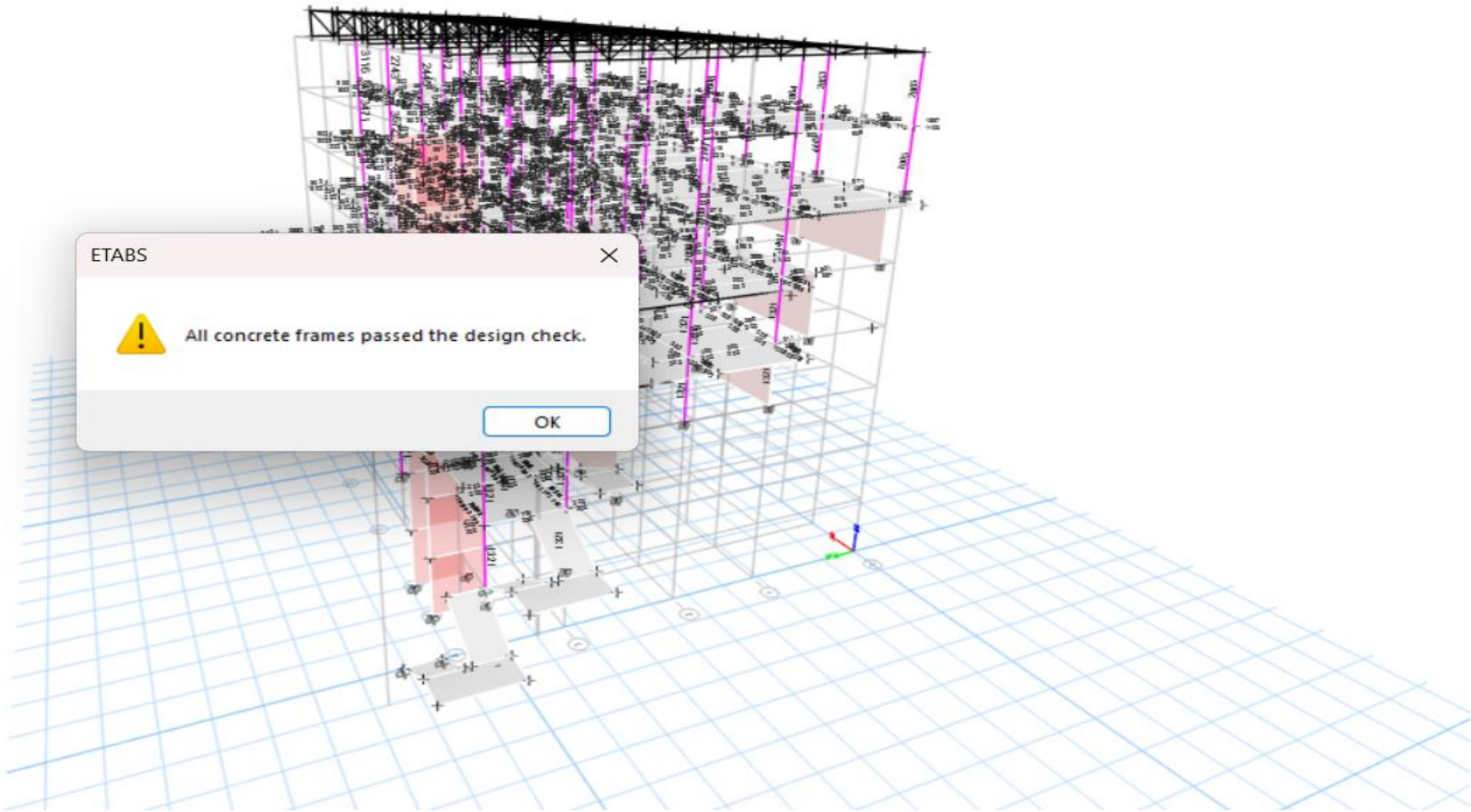


Eqx (ULS)



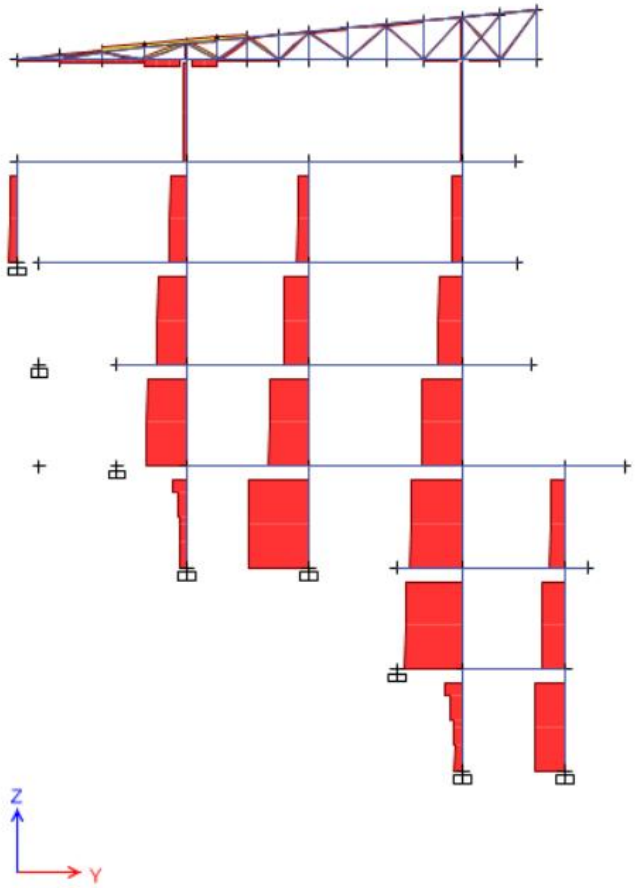
Eqy (ULS)

MODELLING AND ANALYSIS

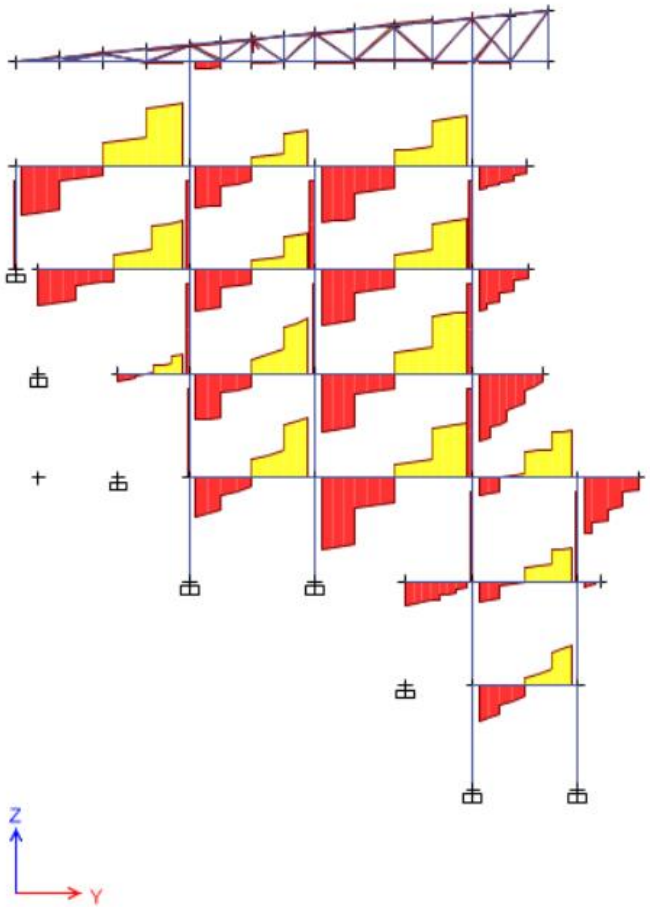


MODELLING AND ANALYSIS

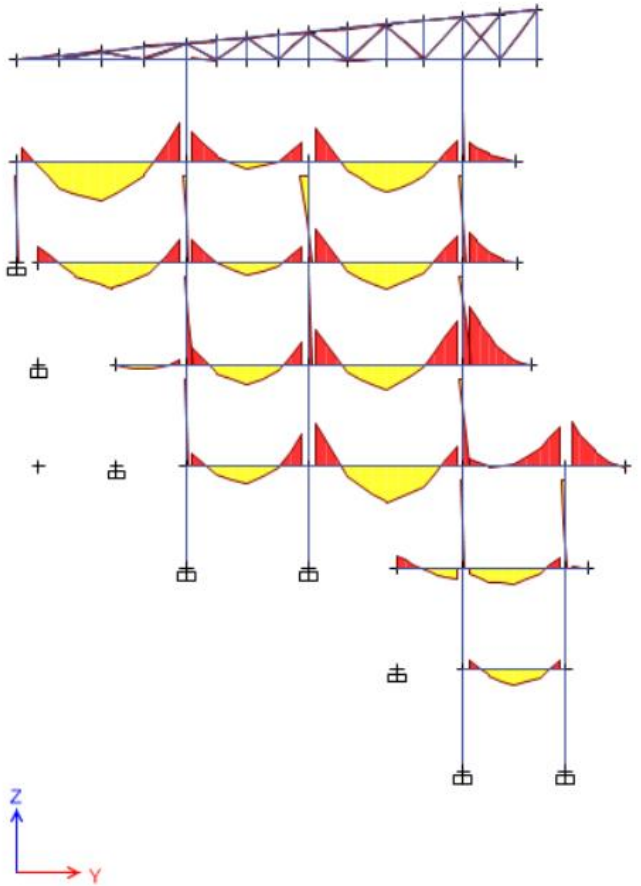
Load Combination : 1.2DL + 1.5LL



Axial Force Diagram



Shear Force Diagram



Bending Moment Diagram

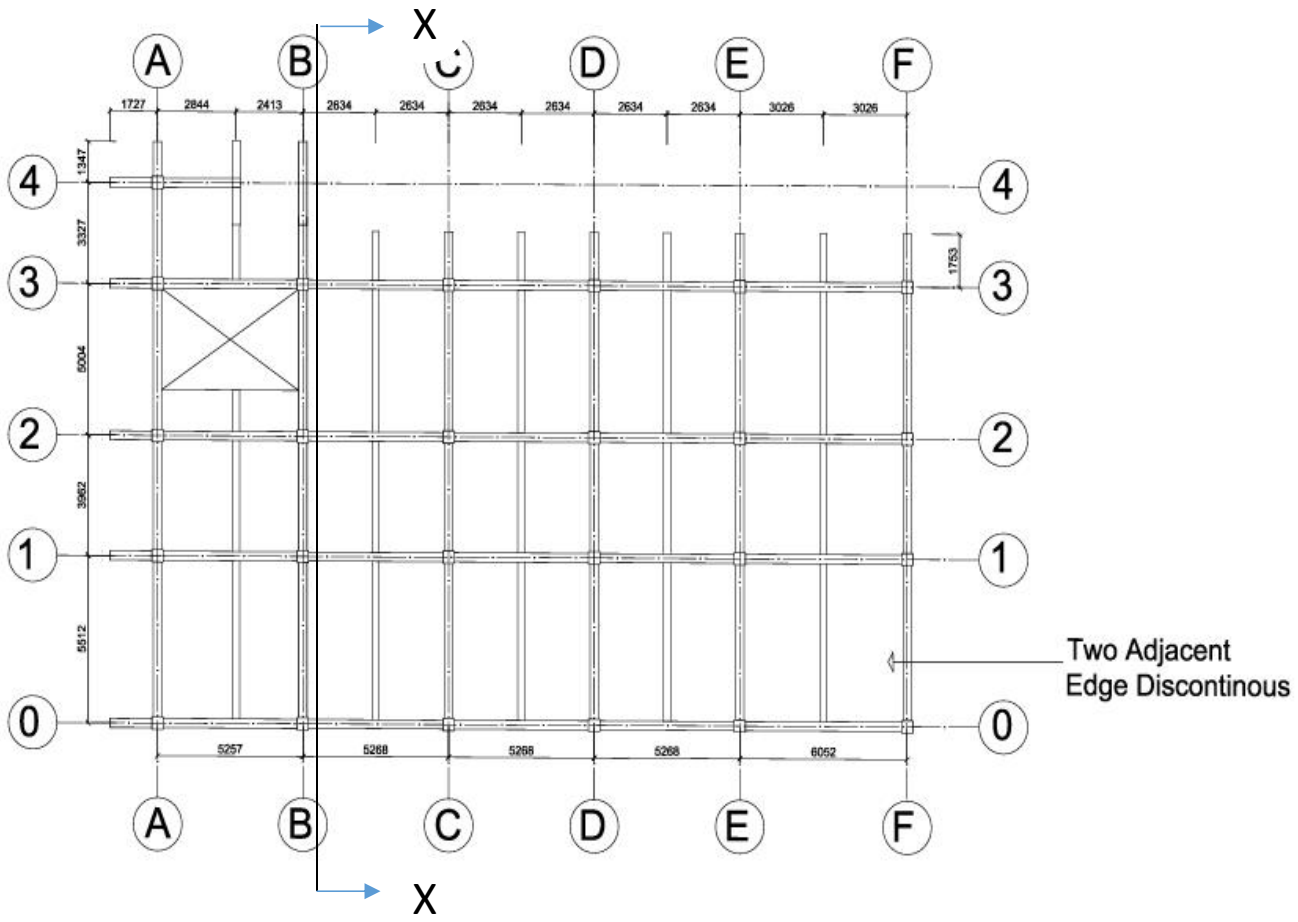
DESIGN OF SLAB

Type of slab= Two-way slab

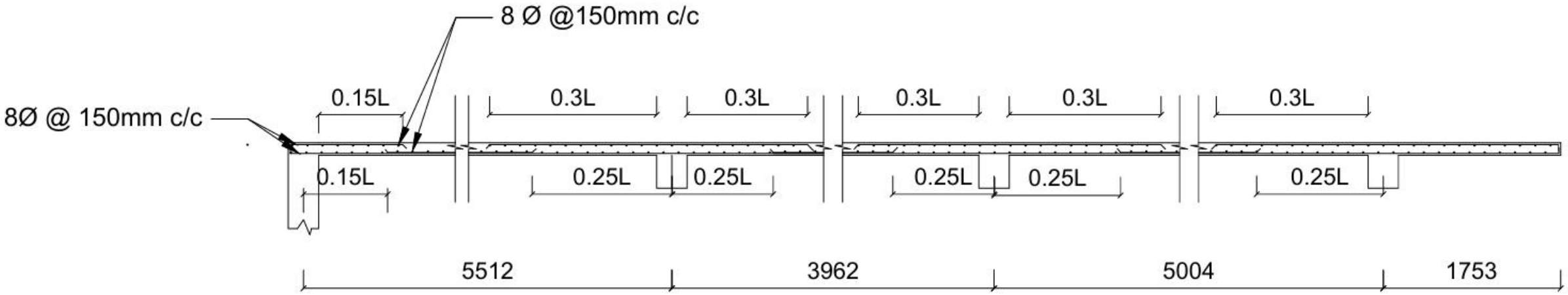
- Panel type = Two Edge Discontinuous
- Effective span length (lx)= 3023 mm
- Effective span length (ly)=5511.8mm
- Effective Depth(d) = 125 mm
- Clear cover = 20 mm

SUMMARY

- Main bars in shorter direction
  (8 mm Ø @ 150 mm c/c)
- Main bars in Longer direction
  (8 mm Ø @150mmc/c)

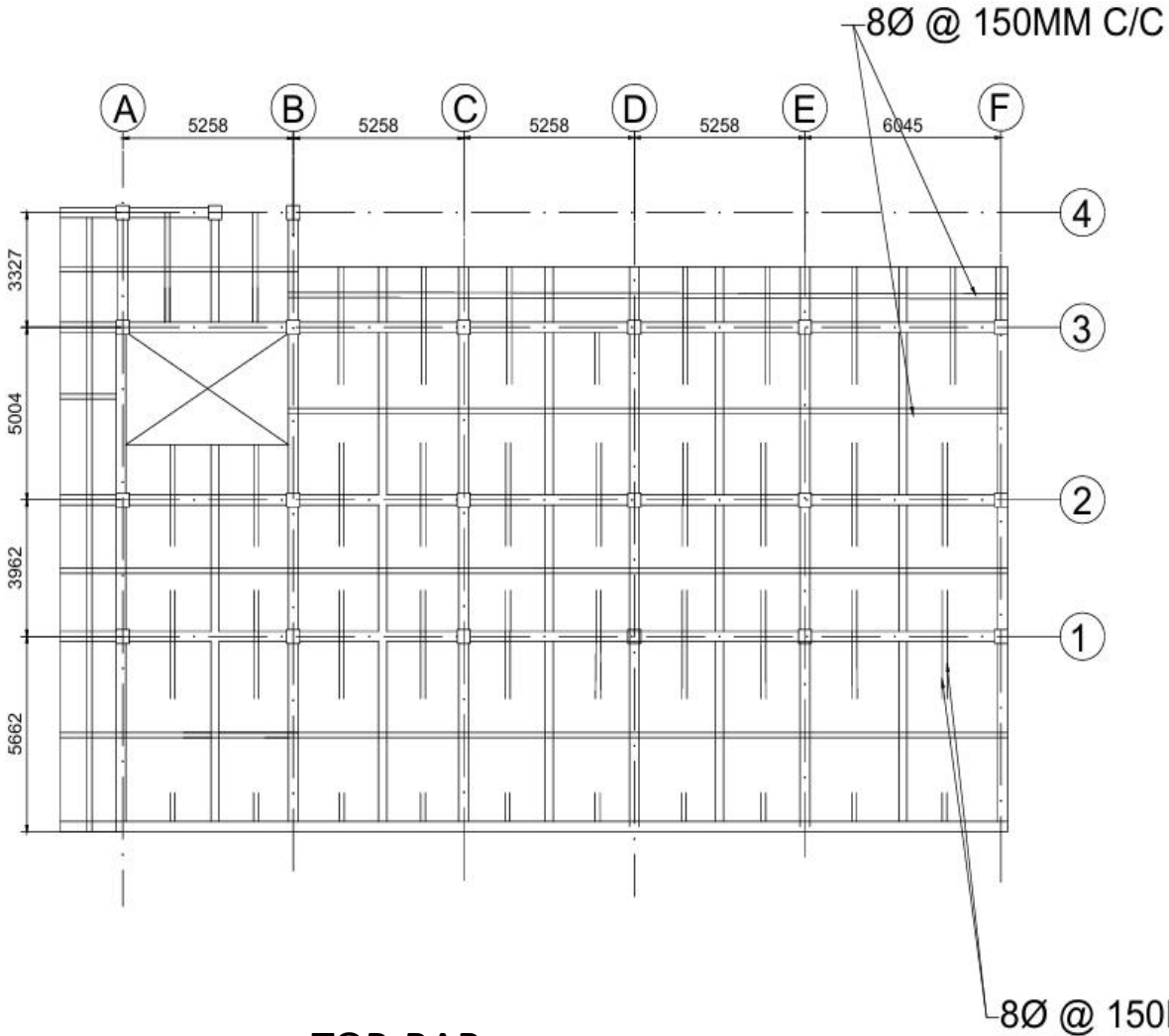


SLAB DETAILING

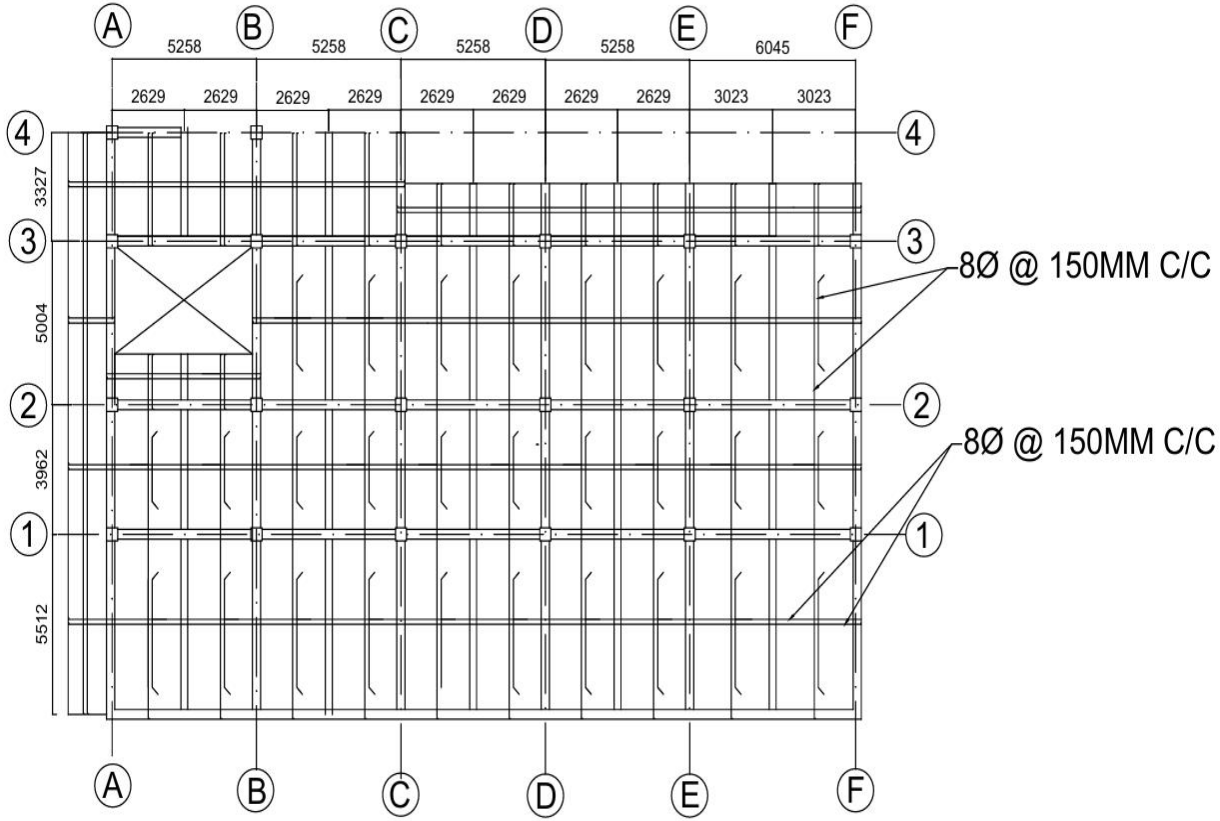


SECTION AT X-X

SLAB DETAILING



TOP-BAR



BOTTOM-BAR

DESIGN AND DETAILING OF BEAM

Primary Beam Detailing

Ultimate Design Moment	At Left Support (KN-M))	Middle (KN-M)	Right Support (KN-M)
Hogging Moment	90.388	0	93.3329
Sagging Moment	28.424	66.56	29.1304

Beam	Size(B×D) (mm^2)	Effective Cover (mm)	Reinforcement			
				At left end	At mid	At right end
Primary beam	300*450	30	Top	4-16mm ϕ	2-16mm ϕ	4-16mm ϕ
			Bottom	4-16mm ϕ	4-16mm ϕ	4-16mm ϕ

For Primary beam, Providing 8ϕ stirrups at 100mm c/c at a distance 2d on either side and 150mm c/c at mid span.

DESIGN AND DETAILING OF BEAM

Secondary Beam Detailing

Ultimate Design Moment	At Left Support (KN-M))	Middle (KN-M)	Right Support (KN-M)
Hogging Moment	0	0	4.379
Sagging Moment	8.3962	28.718	9.157

Beam	Size(B×D) (mm^2)	Effective Cover (mm)	Reinforcement			
				At left end	At mid	At right end
Primary beam	250*400	30	Top	2-12mm ϕ	2-12mm ϕ	2-12mm ϕ
			Bottom	3-12mm ϕ	3-12mm ϕ	3-12mm ϕ

For Primary beam, Providing 8ϕ stirrups at 100mm c/c at a distance 2d on either side and 150mm c/c at mid span.

DESIGN OF COLUMN

Column size : 400x400

- ❑ Length of column = 2.87m
- ❑From Analysis:
  - Design loads (P_u) = 1512 KN
  - Mux = 20 KNm
  - Muy = 30KNm
- ❑ Selection of design combination was done based on percentage of steel required (1.2%).
- ❑Percentage of steel must be 1<pt<4 (Ref NBC:105 2020)

Thus,12-20mmØ @ 102mm c/c. For lateral ties, 8 mmØ @ 150mm c/c pitch distance .For special confinement, Provide 8mm ϕ @ 100mm c/c for a distance of 480 mm on either side from the joint. For splice provide 8mmØ @ 100mm c/c over a length of 1450mm in the middle of column.

DESIGN OF COLUMN

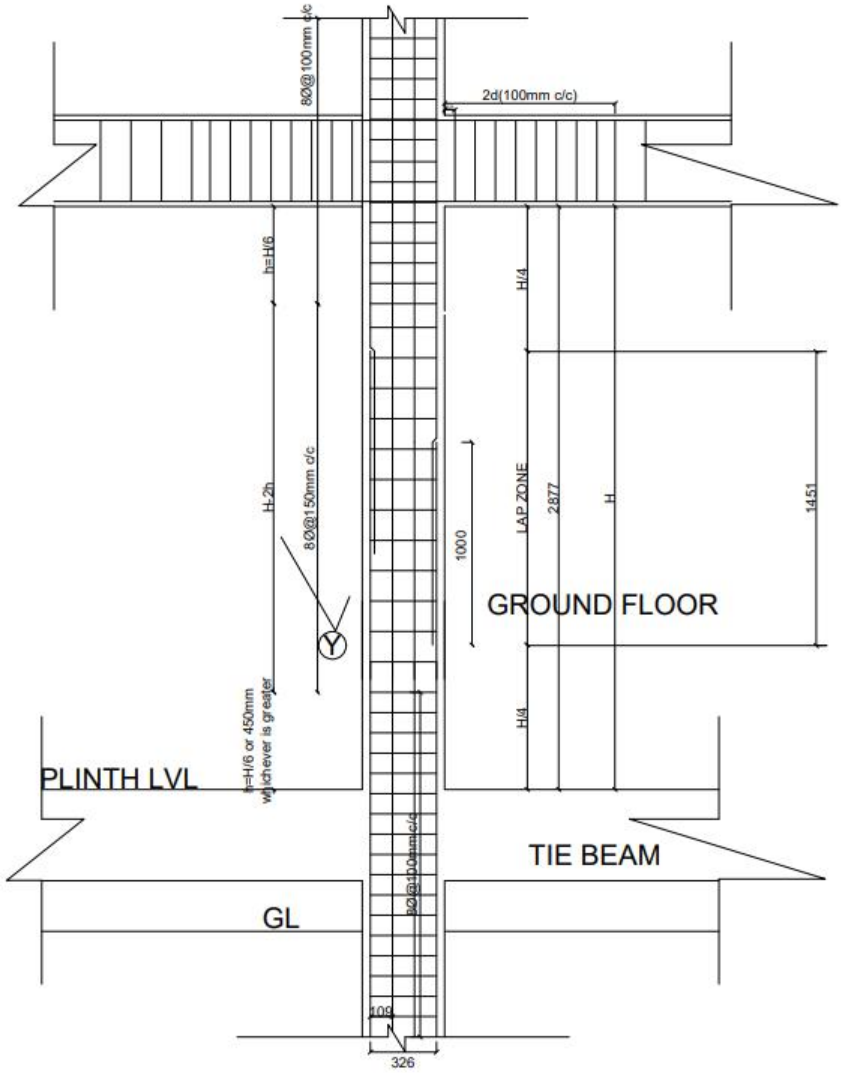
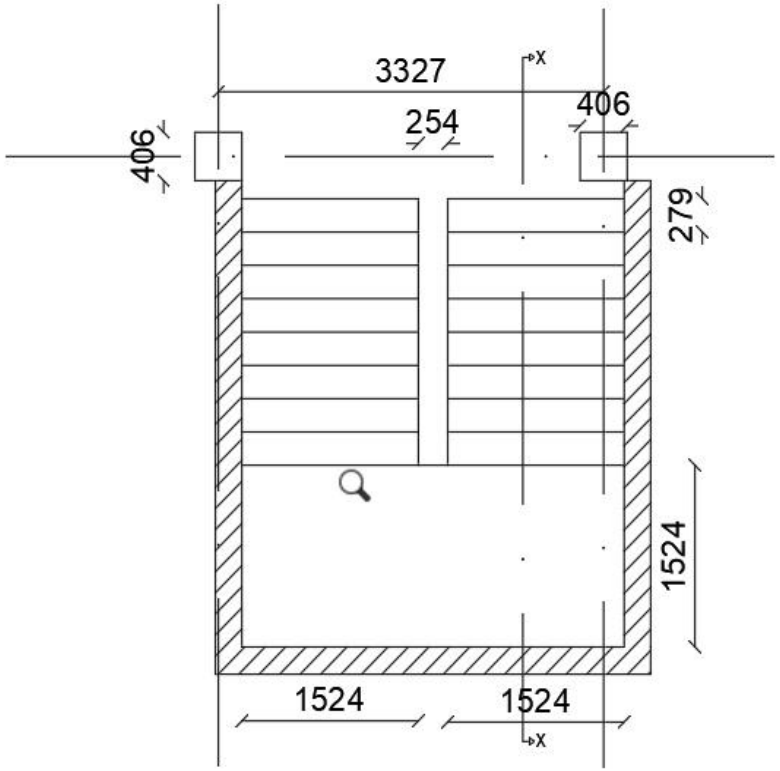


Fig: Longitudinal section of column

STAIRCASE DETAILING

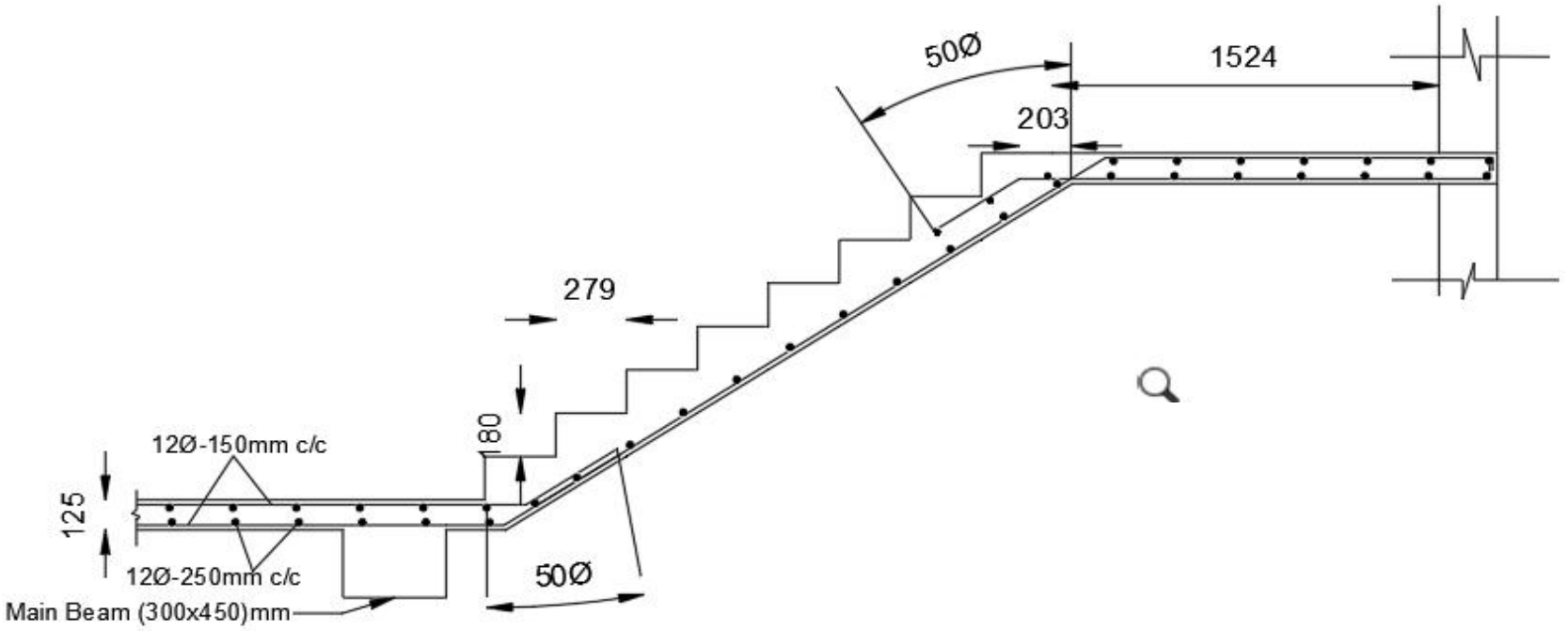
Type of staircase: Doglegged Staircase

- Thickness of waistslab : 150mm
- Effective cover : 30mm
- Riser : 180mm
- Tread : 275mm
- No of Riser : 9 in single flight
- No of Tread : 8 in single flight
- Floor Height :3302 mm
- For Upper and Lower flight
  - ❑ Provide 12mmϕ rebar @150mm c/c for main bar
  - ❑ Provide 12mmϕ rebar @250mm c/c for distribution bar



PLAN OF DOGLEGGED STAIR CASE

TYPICAL SECTION OF DOGLEGGED STAIRCASE



SECTION AT X-X

STAIRCASE DETAILING

Type of staircase: Open well Staircase

For 1st and 3rd flight:

- Effective length= 2942 mm
- Thickness of Waistslab : 175mm
- Effective cover : 30mm
- Riser : 180mm
- Tread : 275mm
- No of Riser : 5
- No of Tread : 4
- Floor Height :3302 mm
  - ❑ Provide 10mmϕ rebar @200mm c/c for main bar
  - ❑ Provide 10mmϕ rebar @300mm c/c for distribution bar

For 2nd flight:

- Effective length= 5248 mm
- Thickness of Waistslab : 250mm
- Effective cover : 30mm
- Riser : 180mm
- Tread : 275mm
- No of Riser : 9
- No of Tread : 8
- Floor Height :3302 mm
  - ❑ Provide 10mmϕ rebar @150mm c/c for main bar
  - ❑ Provide 10mmϕ rebar @200mm c/c for distribution bar

DESIGN OF FOUNDATION

Mat Foundation (Lo)

- Bearing Capacity of soil = 200 KN/m^2
- Depth of Mat foundation = 800mm
- Factored Load = 2166.74 KN
- Service Load = 1444.49 KN

Along X-direction:

- Ast required = 3303.921 mm^2
- Ast min = 960 mm^2

Top and bottom reinforcement = 25mmϕ @ 125mm c/c spacing

Along y-direction:

- Ast required = 1380.47mm^2
- Ast min = 960mm^2
- Top and bottom reinforcement = 20mmϕ @ 200mm c/c spacing

DESIGN OF FOUNDATION

Mat Foundation (L2)

- Bearing Capacity of soil = 200 KN/m^2
- Depth of Mat foundation = 800mm
- Factored Load = 2082.0092 KN
- Service Load = 1388.006 KN

Along X-direction:

- Ast required = 3635.757 mm^2
- Ast min = 960 mm^2

Top and bottom reinforcement =25mmϕ @ 125mm c/c spacing

Along y-direction:

- Ast required = 2413.209mm^2
- Ast min = 960mm^2
- Top and bottom reinforcement = 25mmϕ @ 200mm c/c spacing

DESIGN OF FOUNDATION

Strip Footing (L1)

- Bearing Capacity of soil = 200 KN/m^2
- Shear stress = 0.6175 Mpa
- Width of footing = 3200 mm
- Effective depth of footing:
  - From shear criteria= 256.935 mm
  - From flexure criteria= 225.471 mm

  So, adopt Depth of footing (D)= 350mm

  Provide eff.depth (d)= 350-75

  = 275mm >256.935 mm (ok)
- Ast required = 1918.762 mm^2
- Ast (min) = 1344 mm^2
- Top and bottom reinforcement = 20mmϕ @ 150mm c/c spacing

DESIGN OF FOUNDATION

Strip Footing (L3)

- Bearing Capacity of soil = 200 KN/m^2
- Shear stress = 0.7725 Mpa
- Width of footing = 4000 mm
- Effective depth of footing:
  - From shear criteria= 272.08 mm
  - From flexure criteria= 287.799 mm

  So, adopt Depth of footing (D)= 400mm

  Provide eff.depth (d)= 400-75

  = 325mm >287.799 mm (ok)
- Ast required = 2715 mm^2
- Ast (min) = 1920 mm^2
- Top and bottom reinforcement = 20mmϕ @ 100mm c/c spacing

REAMINING WORKS

- Estimation.
- Str. Drawing of Beams
- Str. Drawing of open well staircase.
- Str. Drawing of foundations .
- Design of shear wall.
- Bar bending schedule.

THANK YOU